Space Technology Research Grants

Modern Estimation Techniques and Optimal Maneuver Targeting for Autonomous Optical Navigation around Small Bodies

Completed Technology Project (2012 - 2016)

Project Introduction

Autonomous Optical Navigation (AON) allows for significant advances in spacecraft navigation accuracy around small bodies located far from Earth, such as asteroids and comets. AON has been used effectively in several previous spacecraft missions, including the Hayabusa and Dawn missions. However, NASAs future goals for exploration of small bodies are significantly more challenging than what has been accomplished to date. In particular, the small-body pinpoint landing accuracy needed for future spacecraft missions planned by NASA will require significantly enhanced navigation accuracy and autonomous maneuver capabilities. To help NASA attain these goals, the research team will investigate the effectiveness of modern orbit estimation techniques and optimal maneuver targeting algorithms for orbiting and landing on small bodies using AON. The research team will build upon Dr. Russells recent experience in 1) advanced estimation techniques, 2) efficient, robust feedback control algorithms for maneuver design, and 3) fast numerical methods for onboard processing. The Spacecraft Autonomous Navigation Toolset (SANT) was created at NASAs Jet Propulsion Laboratory in 2009 to study the landing accuracy achievable with AON using landmarks on small bodies. Analyses with SANT and other tools have shown that standard ground-based navigation can provide landing accuracies on the order of tens of meters, but a closed loop autonomous navigation and maneuvering system is needed for greater accuracy. The research team will use SANT to evaluate modern estimation techniques (i.e. filters) for AON simulations about small bodies. The research team hypothesizes that these filters can provide significant improvement for AON about small bodies using landmarks. These techniques include: The Unscented Kalman Filter. Second- and higher-order Kalman filters, which include higher-order terms of the Taylor expansion of the nonlinear system. The Particle Filter, which uses a set of differently weighted samples of the distribution, i.e. particles. The Adaptive Gaussian Mixture Filter, which represents the probability density function (PDF) as a Gaussian Mixture Model. The research team will compare the navigation performance of these estimation techniques in Monte Carlo simulations to the performance observed with standard Batch-Least-Squares (BLS) and Extended Kalman Filter (EKF) methods. These results will allow the development of a decision engine that determines the best estimation filter to use for particular mission conditions, as well as an auto-recovery feature to allow the onboard spacecraft navigation to recuperate if the OD is partially or completely lost. Advances in autonomous maneuvering algorithms are also needed to achieve future NASA goals. Thus, the research team will develop state-of-the-art optimal maneuver targeting and decision capabilities, implement those capabilities within SANT, and test those capabilities using Monte Carlo analysis. The proposed advances in AON filtering and maneuvering targeting technologies will reduce navigation error, decrease dependence on ground resources, and increase operational agility for future missions. These innovations will serve as stepping stones in NASA's quest to land robotic and manned spacecraft on small bodies with increasing accuracy.

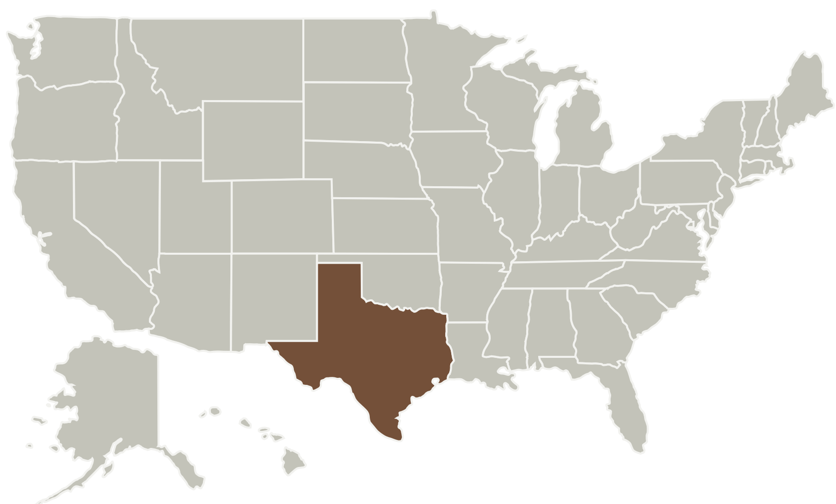
Project Image Modern Estimation Techniques and Optimal Maneuver Targeting for Autonomous Optical Navigation around Small Bodies

Table of Contents

Anticipated Benefits

The proposed advances in AON filtering and maneuvering targeting technologies will reduce navigation error, decrease dependence on ground resources, and increase operational agility for future missions. These innovations will serve as stepping stones in NASA's quest to land robotic and manned spacecraft on small bodies with increasing accuracy.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
The University of Texas at Austin	Supporting Organization	Academia	Austin, Texas

Primary U.S. Work Locations
Texas

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

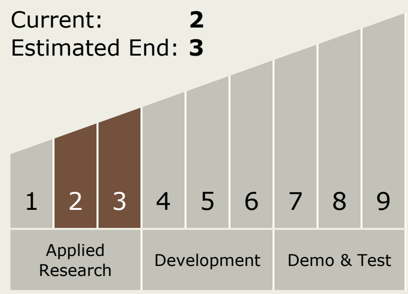
Ryan P Russell

Co-Investigator:

Corwin Olson

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Images

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Project Image Modern Estimation Techniques and Optimal Maneuver Targeting for Autonomous Optical Navigation around Small Bodies
(https://techport.nasa.gov/image/1799)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Areas

Primary:

- TX17 Guidance, Navigation, and Control (GN&C)
  └─ TX17.2 Navigation Technologies
    └─ TX17.2.1 Onboard Navigation Algorithms